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Intermetallic Phases Precipitation in the Duplex Stainless Steels UNS S31803 and UNS S32520 after Aging Heat Treatment at 700 ℃

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Abstract – The intermetallic phase precipitation, mainly sigma (σ) and chi (χ) phases, was studied in a comparative manner in two stainless duplex steels: a duplex type UNS S31803 and a superduplex type UNS S32520. The χ-phase precipitated at ferrite/ferrite grain boundaries prior to the σ-phase precipitation, which occurred preferentially at ferrite/austenite interfaces and at ferrite/ferrite grain boundaries. The σ-phase precipitation is a eutectoid type reaction of ferrite, leading to σ-phase and new austenite. The χ-phase precipitated at lower temperatures and in smaller amounts than sigma. The χ-phase is metastable in the studied steels and was consumed during the σ-phase precipitation.

Duplex stainless steels (DSSs), with ferritic-austenitic microstructure, have excellent mechanical properties and corrosion resistance. DSSs are widely used in the chemical industry and in offshore technologies, where a combination of high corrosion resistance and good tensile strength is required.

When exposed to temperatures lower than 1000 ºC, DSSs are subject to various phase transformations. In the 970 to 600 ºC temperature range, intermetallic phase precipitation may occur, mainly the sigma (σ) and the chi (χ) phases [1,2]. The formation of such phases is undesirable so that careful processing and use of the steel are needed to avoid or, at least, to minimize them. The χ-phase has been less studied than the σ-phase. The main objective of the present work is to study the intermetallic phase precipitation, mainly sigma and chi phases, in two stainless duplex steels: UNS S31803 with 0.16%N, 22.5 %Cr, 5.5%Ni and 3%Mo and UNS S32520 with 0.22 %N, 24.9 %Cr, 6.5%Ni and 4.0%Mo in a comparative manner. Firstly, the samples were solution annealed at 1050℃ for 30 min followed by water quenching to produce a balanced ferrite/austenite microstructure. The aging heat treatments were then carried out at 700℃ for 2 and 4 h. Several complementary microstructural analysis techniques have been employed such as optical microscopy (OM), scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy analysis (EDS), X-ray diffraction analysis (XRD), magnetic and hardness measurements. The σ-phase precipitation is a eutectoid type reaction of ferrite, leading to σ-phase and new austenite. The χ-phase precipitated in smaller amounts than sigma. The χ-phase is metastable in the studied steels and was consumed during the σ-phase precipitation (Figure 1). The high susceptibility of the duplex stainless steels to intermetallic phase formation is frequently attributed [3,4] to the ferrite chemical composition; richer in sigma forming elements (Cr, Mo and Si) and poorer in austenite stabilizing elements (C, N and Ni).

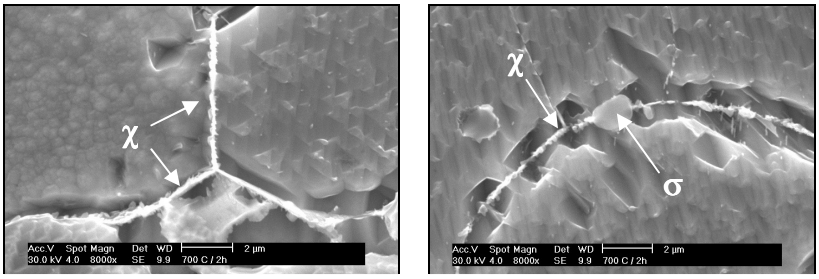

Figure 1: Scanning electron microscopy micrographs of chi e sigma phases in the duplex stainless steel in the aged condition: 700 ℃ for 2 h followed by quenching in water. Etching: V2A-Beize.

References

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